DEPARTMENT OF AGRICULTURE,
CEYLON.

BULLETIN No. 40.

# THE TEA TORTRIX.

(*Homona Coffearia,* Nietner.)

*N. K. JARDINE, F.E.S.*
*Entomologist for Tea Tortrix.*

Peradeniya,
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# PREFACE.

This publication is the preliminary report of the Entomologist for Tea Tortrix on the investigations that have been carried out during the past year.

Great assistance has been given by estate superintendents, who have co-operated with the Entomologist in the up-country experiments, and it is due to their help and support that the investigations have been hastened. To these superintendents, as also to those who have supplied data from their estates, and to those who have supplied material to the laboratory at Peradeniya for the research investigations, the thanks of the Department are due.

Mr. Jardine also wishes that his personal thanks should be tendered to Messrs. R. J. Neale, Huntley Wilkinson, W. Ormiston, and R. Senior-White for much valuable assistance accorded to him in the pursuit of his investigations.

F. A. STOCKDALE,
Director of Agriculture.

June, 1918.

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**DEPARTMENT OF AGRICULTURE, CEYLON.**

**BULLETIN No. 40.**

# THE TEA TORTRIX.

(*Homona coffearia*, Nietner.)

(Synonyms: *Tortrix coffearia*, Feld. in lit. Nietner. *Capua coffearia*, Nietner, Enem. Coff. Ceyl., 1861. *Pandemis* (? *Capua*) *menciana*, Walker, E. C. Cotes, Ind. Mus. Notes, Vol. III., No. 4, 1896. *Homona fasciculana*, Walker, List Lep. Het. Brit. Mus., Vol. 28, p. 424, 1863.)

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## History of the Insect.

THE insect was first described by Nietner in 1861 as feeding upon coffee, but was at that time not a pest, as Nietner remarks in his Enemies of the Coffee Tree, "it is not at all common." Apparently no further mention was made of the insect for twenty-eight years, when in 1889 it was first brought to the notice of Mr. E. E. Green, late Government Entomologist of Ceylon, and described and figured by him* as doing considerable damage to tea in the Dimbula district. Mr. Green mentions in his report of 1911,† "the plague ran its course and then subsided, nothing more being heard of it for about ten years, when a virulent attack was reported from Upper Maskeliya."

In 1903 the insect developed alarmingly in several districts of lower Central Province, and evinced so serious an aspect that one enterprising planter (Mr. Neale, of Bogawantalawa) studied its life-history, which enabled him to furnish valuable information in a report to the Department of Agriculture in 1915. The insect appears to have diminished greatly in

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* Insect Pests of the Tea Plant. E. E. Green, 1890.

† Entomological Notes. E. E. Green, T. A., Vol. XXXVI., No. 4, April, 1911.

numbers, causing no anxiety until 1905, when it re-appeared in isolated areas in the same districts. From 1911 to 1914 it again developed alarmingly, spreading over a vast area, embracing practically the whole of the lower half of the Central Province, and calling for a recognition of its seriousness. Circular letters were issued from the Department of Agriculture to all the Planting Associations for information regarding its occurrence and the loss of tea attributed to it. The information supplied excited apprehension, and it was decided, by the Planting Community, in May, 1915, to appeal to Government to sanction the appointment of an Entomologist to investigate this pest.

## Geographical Distribution.

The exact geographical distribution has not yet been accurately ascertained. One may assume with a certain confidence that the insect is distributed over the whole tea-growing areas of the Eastern Hemisphere, but this assumption requires corroboration. There is reason to believe it occurs in countries and districts where tea is not grown, for it is, broadly speaking, omnivorous, its range of food plants being very wide ; and as it is capable of propagating at elevations of 500 feet to 6,000 feet, and at temperatures ranging from 91 degrees to 30 degrees, it is admirably adapted for wide distribution.

It is found throughout the tea districts of North-east India, but is there of comparatively little importance as a pest of tea. "Flush worm" has been recorded from South-west India (Mysore),* but whether the "flush worm" is identical to our own (*H. coffearia*) has yet to be determined.

## Distribution in Ceylon.

The distribution of the pest in the Island to-day may be said to extend completely over the southern half of the Central Province, taking a line through Kandy, and extending in

* Some South Indian Insects. Fletcher.

a narrow belt from Rassagala in Sabaragamuwa into Uva through Haputale, widening out into a wedge through Demodera and Badulla up to Madulsima.

Tortrix was reported from three estates in the Kelani Valley in 1915, but has not been reported in the district since.

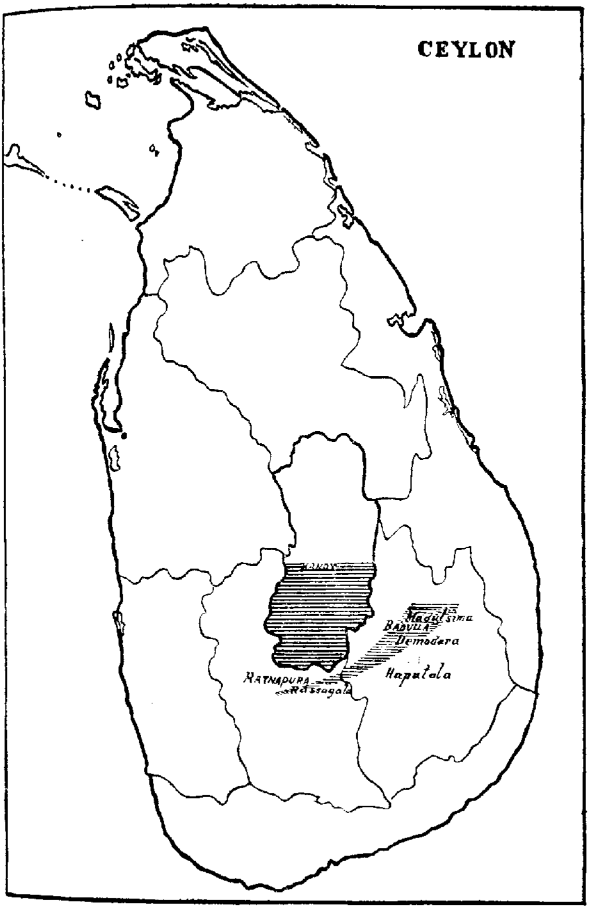
### Food Plants.

The following is a list of plants on which Tortrix has been found to propagate up to date :—

| | | |
|---|---|---|
| Asclepiadeæ | Stephanotis | Stephanotis |
| Amaryllideæ | *Eucharis grandiflora* | Lilly |
| Compositæ | Chrysanthemum | Chrysanthemum |
| | *Aster tripolium* | Michælmas Daisy |
| Euphorbiaceæ | *Acalypha* sp. | |
| Geraniaceæ | *Pelargonium* spp. | Geraniums |
| Lauraceæ | *Cinnamomum camphora* | Camphor |
| Leguminosæ | *Acacia decurrens* | Acacia |
| | *Canavalia ensiformis* | Sword Bean |
| | *Crotalaria* vars | |
| | *Erythrina lithosperma* | Dadap |
| | *Pithecolobium saman* | Inga Saman |
| | *Vigna sinensis* | Cow Pea |
| Myrtaceæ | *Eucalyptus robusta* | Gum |
| | *Psidium cattlezanum* | Red Guava |
| Proteaceæ | *Grevillea robusta* | Grevillea |
| Rosaceæ | Rosa vars | Rose |
| Rutaceæ | Citrus spp. | |
| Sterculiceæ | *Theobroma cacao* | Cacao |
| Urticaceæ | *Artocarpus integrifolia* | Jak |
| Verbenaceæ | *Duranta plumieri* | Duranta |

### Climatic Influence.

The south-west monsoon is responsible for a general distribution of the insect. All ridges exposed to this wind are liable to be infested. The investigator has suggested, and in two cases advised, the planting of Dadaps in double rows along south-west ridges to test their practicability as Tortrix traps. It is expected that this screen of Dadaps will break the drive or forced flight of the adults, and, with careful and periodical




DISTRIBUTION OF H. COFFEARIA IN CEYLON.

examination of the trees, eggs and larvæ may be collected and destroyed, and a general distribution of the pest through the tea thus prevented.

Since these Dadap screens have been planted, experience and observations have brought to light a more efficacious barrier, which is discussed under Preventive Measures.

The effect of climate has been very noticeable. Heavy and continuous rains appear detrimental to the propagation of the insect. Those which have completed the final ecdysis appear to pupate prematuredly in an endeavour to escape the harmful circumstances. An interesting point in connection with this is that 70 to 75 per cent. of these prematuredly pupated insects are males. It is noticeable that in inclement weather the majority of a brood turn out males.

At first the investigator was led to believe that this was a question of sex determination by environmental influence, but it appears by investigation to be merely a matter of the males being more capable of enduring adverse circumstances. Conditions opposing the continuation of the species cause what appears an excess of males, but which in reality is an elimination of females. This is probably one of the reasons why in excessively wet weather the insect is rapidly reduced in numbers, there being a too meagre proportion of females to keep up the necessary rate of increase of the insect.

Another most important reducing factor in wet weather is "scour." This malady takes the form of a severe diarrhœtic condition of the larvæ; it is brought about by the absorption, during feeding, of a super-abundance of moisture, which appears to hinder assimilation, and sets up an irritated state of the alimentary canal. Thorough nutrition is prevented, the larvæ become anæmic, development is arrested, and death quickly occurs.

Among other diseases influenced by wet weather to which Tortrix is subject may be mentioned three fungi: An *Isaria* and a *Cephalasporium* on the larvæ, and a *Gibellula* on the pupæ.

Dry weather favours the development of the insect. Tortrix generally makes its appearance on the tea in dry months; also "scour" and fungoid diseases are not prevalent in dry seasons.

## Loss of Crop.

It is difficult to ascertain the exact amount of crop lost through Tortrix, but as numerous planters have provided estimates, I append a few figures to give an indication of the seriousness of the pest.

In one district where 900 acres were attacked in 1914 the loss was estimated at 150,000 lb. of made tea. On one estate of another district, where 100 acres were attacked, the loss was 60 to 100 lb. an acre. On yet another, where 150 acres were infested, 100 to 110 lb. of made tea were lost per acre. These figures have been supplied by planters. Many estates have lost more where the attack has been exceptionally severe, but the average quoted is by no means exaggerated. Assuming 150 lb. made tea to be the average loss per acre during a severe attack, this represents 600 lb. of green leaf.

Since August, 1917, sixty-three estates have been more or less rigorously attacked. The area infested on each estate averages 50 acres, the total area injured by Tortrix being 3,150 acres. As the attacks were not exceptionally severe, to err on the safe side, the average loss of 600 lb. green leaf is reduced to 400 lb. per acre. Thus, on 3,150 acres 1,260,000 lb. of leaf have been destroyed since August last year. In hard cash this represents, at 6 cents per lb., Rs. 75,600, or Rs. 1,200 per estate. When it is understood that last year Tortrix was not severe, appearing only here and there, and that the attacks were not continuous for nine months, one can appreciate the seriousness, and loss, of a long, severe, and widespread attack.

## General Scheme of Investigation.

Owing to the variation of climate over the Tortrix area the investigator saw the necessity of opening up experiments in different districts in order thoroughly to ascertain the exact periods occupied in the various stages of the metamorphosis of the insect. Assistance was readily given, and seven up-country experiments were instituted in co-operation with estates: two in Maskeliya at elevationsof 4,200 and 5,000 feet, one in the Agrapatanas at 4,000 feet, one in Talawakele at

4,200 feet, one at Pundaluoya at 5,200 feet (and subsequently at 4,200 feet), one at Bogawantalawa at 4,000 feet, and one at Dikoya at 4,200 feet.

The objects of the experiments were :—

(1) To ascertain the exact periods occupied in the various stages of the life-history of the insect: egg, larva, pupa, and adult.

(2) The proportion of males to females.

(3) How soon after emergence does fecundation take place?

(4) How long does mating occupy?

(5) How soon after coition does the male die?

(6) How soon after fertilization does egg-laying take place?

(7) How long does egg-laying take, and how many eggs and egg-masses are laid per female?

(8) At what period, day or night, does egg-laying take place?

(9) How soon after egg-laying does the female die?

(10) Does the larval environment immediately before pupation appear to have any control of sex, or to influence the colour of the insect?

(11) Does the pupal environment influence sex or colour?

(12) Does temperature appear to influence sex?

Though these experiments called for a great deal of time and close observation on the part of the planters who undertook them, they were, and are still being, attended to with assiduous care, and the information received from them has proved of great value to the investigation.

Similar experiments were instituted in the laboratory at Peradeniya, and data compared and checked at regular intervals with those recorded in the up-country experiments.

Experiments with larval and pupal parasites, food plants, causes of diseases of larvæ, fungi attacking larvæ and pupæ, together with investigations into the relative value of predacious enemies as a possible check to the insect have been carried out in the laboratory, and an average of ten estates visited per month.

It would be to the advantage of every estate if the local branches of the Planters' Association would influence their members to keep in monthly touch with the laboratory.

Every effort has been made to encourage co-operation between the estates and the laboratory at Peradeniya. In further researches it is hoped that closer co-operation will yet be possible, and estates are invited to send in to the laboratory a monthly letter stating whether the pest is present, in what fields, in what form (egg, larva, moth), whether prolific or not, the condition of the tea harbouring the pest, the age of the attacked tea from last pruning, the occurrence of diseased larvæ, the dates of the appearance of the moths, the direction in which the pest extends its range, the prevailing wind, and the rainfall.

### The Reason of the Sudden Appearances of the Pest in a Field.

A point which appeared remarkable and caused considerable speculation was that fields of tea would often be entirely free from Tortrix one day, and a few days later the insect would be found on the bushes here and there in the fields, in spite of the fact that neighbouring fields and estates had no Tortrix on the tea. In several instances the absence of wind—a distributing agent—appeared to further complicate the problem.

On numerous occasions Grevillea and Dadap leaves attacked by an insect were sent to the laboratory for examination and identification. The insect proved to be Tortrix; inquiries and field examinations proved that the tea in the fields from which these leaves were taken was not attacked by Tortrix. The investigator waited until the typical sudden appearance of Tortrix was recorded and visited the fields. Upon climbing and examining a tall Grevillea tree in close proximity to the bushes on which the attack had appeared it was found that Tortrix was in abundance on the Grevillea, and the natural conclusion was that the insect had developed and propagated on the Grevillea, and possibly through overcrowding and a lack of sufficient food the larvæ had dropped down by means

of their silken threads to the tea below. Corroboration of this was made in several other instances where the tea being free of Tortrix, the shade trees (Grevillea, Acacia, Albizzia, and Dadaps, the two latter not so often as the two former) proved to be full of the insect.

It is difficult on a superficial examination to recognize the presence of Tortrix on Grevillea ; owing to the smallness of the leaflets and their lying closely one to the other, there is no sign of the binding and curling of the leaves so typical of Tortrix on tea, and an attack on Grevillea and Acacias can be easily overlooked.

There is no doubt that the adult insects alight on these shade trees and lay their eggs, a colony being founded. This fact may prove of great importance in ultimately arresting the spread of the insect. A narrow belt of jungle is a most efficient barrier to the dispersion of an insect. The Tortrix moth is a feeble flyer, and is chiefly dependent upon the wind for its distribution. Isolation belts of useful trees, such as those mentioned above, would insure a certain protection against the infection of the insect, or of re-infection after remedial treatment.

## The Insect.

This well-known lepidopterous pest of tea belongs to the family Tortricidæ ; the name implies the characteristics of the larvæ, the habit they have of rolling leaves together or twisting and distorting portions of their food plants. This habit of the family has been much discussed, and has been attributed to three distinct causes : (1) The direct operations of the larva ; (2) the contraction of the silk when drying ; and (3) changes in the mode of growth of the parts of the plant resulting from interference of the caterpillar.

In the case of Tea Tortrix there is absolutely no evidence to show that the twisting or curling of the leaves is due to any other cause than the direct operations of the larva. The insect curls the leaves around itself for the express purpose of protection. On many occasions the investigator has placed the larvæ, together with the larval parasites, in confinement, there being a few leaves in the tubes and boxes used.

Immediately the larvæ have sensed the danger of the parasites, they have hurried to a leaf, taking a position along the midrib, and quickly thrown a net of silk over themselves from side to side of the leaf, gradually curling it over themselves. This protective habit of the larvæ has been a source of trouble in their parasitism by the *Proctotrypidæ* in the laboratory.

*The Eggs.*—The eggs are flat, oval-shaped objects, laid one overlapping the other; very small, measuring 0·70 of a millimetre, and laid in masses. The entire egg-mass is flat, long, and very slightly narrower at one end; an average mass measures 13 mm. long by 4 mm. at the wider end and 1 mm.—or the width of two eggs, not forgetting the overlap—at the narrow end, and contains 125 to 150 eggs.* The whole mass is covered by a varnish-like film.

This narrowing at one end is hardly noticeable to the casual observer, but the reason of it is obvious when egg-laying is closely watched. The rate of egg-laying is at first normally rapid, and the eggs are laid in rows of 7 to 10. The first row is deposited, the second slightly overlaps the first, and the third overlaps the second, and so on. As egg-laying progresses the rows become narrower, *i.e.*, there are less to the row—but the overlap on the adjoining eggs may be less—until finally but a few remain to be laid. The rate of egg-laying gradually decreases when about 60 per cent. of the total have been deposited; the last 10 to 20 eggs take a long time in the laying, and are slightly larger than the rest.

The eggs are laid in rows, not the length of the mass or indiscriminately, but from side to side of the mass. The rows are usually slightly curved. After the first row is deposited the female lays the first of the second row overlapping the last of the first row, then proceeds to lay to the other side of the mass, laying the first of the third row on the last of the second. This process goes on until the rate of egg-laying decreases, when less are deposited per row. The narrowing of

* Mr. Green in his reports puts the number of eggs per mass at 200 to 500, which he considers a very moderate estimate, but, taking the average from over 15,000 egg-masses examined in 1917–18, the average was 125 to 150 eggs per mass.

the egg-mass may be traced to when egg-laying becomes less rapid. It is apparently an indication to the female that her stock of eggs is diminishing and the tapering off process commenced. The only suggestion the investigator cares to put forward at present as a possible reason for this typical pointing or narrowing down of the egg-mass is that by this shape, and the position of the mass on the leaf, it presents a surface giving least resistance to the stopping or gathering of water around the eggs. The eggs are generally laid parallel to a minor vein (often the central vein itself) with the broad end of the mass towards the margin of the leaf, and ninety-nine cases out of a hundred on the matured leaves. The matured leaves rarely take an upright position on the bush, but tend to hang downwards. Therefore, any moisture accumulating on the leaves will not be stopped by, but glide past, the egg-mass.

One often encounters small round masses of eggs, masses entirely lacking the narrow end ; these are interrupted groups of eggs, the female having been disturbed during her laying, and the tapering process not commenced.

When the egg-mass is freshly deposited, it is of an opaque white colour, changing in the course of four days to a dull yellow, being a conspicuous object against the green of the tea leaf. As the embryo larvæ mature, the mass becomes a denser yellow, changing to a striped mass of black and yellow a few hours before hatching. This striped effect is caused by the shining black heads of the now matured larvæ showing through the egg-shells. When the insects have hatched, the empty shells remain, making the mass a silvery white in colour.

*The Larva.*—To emerge from the egg the larvæ bite their way through the egg-shell. The newly-hatched larvæ are small reddish-yellow creatures with black heads ; they measure about 2 mm. in length. They differ from the older caterpillars, in that they lack the shining black plate on the first segment, and the head is entirely a different shape, being more oval and somewhat heart-shaped at the posterior dorsal region (Fig. 5). There are a few pale hairs on the body. The matured larva (Fig. 3) is of a dark green colour, with a black

shining head carrying a few bristle-like hairs (Fig. 4). It measures an inch to an inch and a quarter in length. There are twelve segments : the first carries a hard shiny black plate, which covers its whole dorsal surface and a third of the upper part of the sides ; and a pair of jointed legs. The second and third each carry a pair of jointed legs. There are five pairs of pro-legs or " sucker-feed," situated on segments six, seven, eight, and nine, and an anal pair on the last or twelfth segment. (See Fig. 11.) The caterpillar is sparsely covered with pale hairs distributed in uniform manner, there being four hairs to each segment dorsally, and one on each side of each segment. The last segment carries three pairs of hair on the dorsal surface. The lateral or side hairs arise from just above the spirades.

Very often the investigator has found larvæ with brown heads and brown thoracic plates, and these when matured proved to be slightly larger than the black-headed specimens. It was at first thought they were a species distinct from the one just described, but upon the development of the moth they proved to be identical. At present the investigator is unable to give a reason for this peculiar colour difference.

*The Pupa.*—The pupa or chrysalis is naked, free of larval covering or puparium, tawny-yellow to dark brown in colour, the dorsum or back being of a darker shade. The wing cases are well defined; the eyes somewhat reddish; the abdomen chestnut-brown. The dorsal surface of the abdominal segments are furnished with minute sharp protuberances or teeth which lie across the segments in two rows ; the anterior or front rows are more developed than the posterior or hind rows. The last two segments lack these teeth. These tooth-like spines are for the purpose of allowing the pupa to change its position ; for as the pupa lies upon its back, it can, by wriggling on the teeth from its tail which is fixed to the leaf, change its position at will. As in the larva, each segment bears two pairs of cilia or hairs. The penultimate segment is furnished with a sparse fringe of hair which points backwards. There is a stout, triangular, flattened terminal spine (the cremaster) at the extremity of the last segment, and this spine has eight hooks, four on the dorsal surface, each pair

pointing in opposite directions ; one on each side towards the dorsal surface ; one on each side towards the ventral surface. The cremaster is for the purpose of the pupa fixing itself to the object which is to support it.

The male and female pupæ differ in size and slightly in colour. The male is 7 mm. long, and is yellow-brown with bronze-yellow wing cases. The female is 11 mm. long, and is a darker uniform brown than the male.

*The Moth.*—There is a distinct difference between the male and female in size and colouring. The female (Fig. 1) is brownish-yellow in colour. Head and thorax brownish-yellow; eyes generally black, sometimes reddish-brown; antennæ simple and thread-like in appearance, and as long as head and thorax together; thorax without a crest of scales. Fore wings brownish-yellow with a darker patch of the same colour on the shoulder; there is an oblique, slightly sinuous medial band of the same shade from the centre of the front edge of the wing to the inner margin, with a similar band across the apex; the borders of these bands are somewhat coppery in colour; the apex pointed, the outer boundary—the position between the upper and lower margins of the expanded wing—is slightly arched and fringed with scales. No shoulder fold of the wing as in the male. Hind wing of a uniform coppery colour, and fringed with scales along the lower margin. Legs of the same colour as the hind wings. The wings when at rest lie over the body, their outlining being of the same shape as the section of a bell. Wings expanded 25 to 28 mm.

The male (Fig. 2) is gray in colour. Head and thorax gray and densely scaled, the thorax carrying a tuft of gray scales on the dorsal surface ; eyes reddish-brown ; antennæ fringed with hairs and thread-like, reaching to the middle of the wing. Fore wing gray, narrow, with an oblique slightly sinuous medial band of light brown from the centre of the front edge of the wing to the centre of the inner margin ; a dark gray spot bordered by black is situated at the centre of the front margin ; a sinuous brown band bordered by darker brown crosses the apex of the wing ; the outer boundary arched and fringed with gray scales. There is a prominent " costal fold " of scales at the shoulder, curled towards the upper surface and

densely scaled. Hind wings of a uniform dark gray fringed with scales at the outer margin. Legs of a coppery colour. The wings when folded are not so typically bell-shaped as in the female ; they are more acutely " pitched," like the roof of a house. Wings expanded 15 to 17 mm.

There is a great variety in the colour of the markings of the fore wings of both sexes. Many instances in the female show no markings at all ; sometimes they are gray, sometimes dark brown, and even to black shoulders. In the male instances of brown, orange-brown, and even black markings have been recorded. The typical markings are more constant in the male. Experiments were made to ascertain whether the colour scheme was dependent upon the environment of the larvæ before pupation and that of the pupæ ; results of these experiments will be found elsewhere.

*Flight of the Moths.*—There is a noticeable difference between the flight of the male and female. The female when disturbed will fly, with a quick fluttering of the wings, in a wide circle, evenly and in the same plane, returning to within a few yards of the place she was disturbed from. The male never flies in the same plane, but " tumbles " like a tumbler pigeon and zig-zags like a snipe ; the direction of his flight is not a circle, nor is it sustained ; rather does he zig-zag from bush to bush when disturbed.

### Life-history.

The actual life-history of the insect from the laying of the egg to death is six to eight weeks :—

| | |
|---|---|
| Egg to larva .. | 1 week 3 days |
| Larva to pupa .. | 4 weeks to 5 weeks |
| Pupa to adult .. | 1 week |
| Adult to death .. | 1 week |

The eggs are laid upon the upper surface of the old or matured leaves of the tea, and generally low in the centre of the bush. It is believed the eggs are laid on these particular leaves and in the densest part of the bush in order to afford the newly hatched larvæ protection from predaceous enemies ; for the larvæ remain on the undersides of the matured leaves until the first ecdysis (moult) is passed—a matter of five to eight

days. Were the larvæ to wander about the exposed leaves of the bush, there is little doubt a great many would become prey to their enemies. The incubative period of the egg is from ten to twelve days at elevations of 3,000 feet to 4,500 feet; at Peradeniya (1,600 feet) it is seven to ten days. The presence of empty egg-masses on the leaves is no indication that the larvæ have lately hatched, for these masses will remain on the leaves until the leaf drops to the ground. Occasionally the empty eggs are devoured by field cockroaches and ants.

It is exceedingly difficult to ascertain exactly the egg-laying seasons of the moth, for, from evidence gathered, there is but one month of the year when eggs are not to be found in the Tortrix areas. It is essential that the egg-laying seasons for various districts shall be determined as accurately as possible, for numerous points in the question of preventive and remedial measures hinge upon this vital detail. To trap moths which have already laid their eggs, and males which have fertilized females is a waste of time and money; but by knowing the egg-laying seasons and trapping at the time of laying the waste can be obviated. Again, if egg-parasites are to be used to advantage the knowledge is essential. It would appear July, August, and September are the chief egg-laying months—there being two broods in rapid succession—as they show egg-masses in a greater number of districts than in any other months. February and March come second in importance; while January, October, November, and December rank equally as important as the other.

The following table shows the months when, and districts where, eggs were found during the year 1917–18 :—

1917.

July : Maskeliya, Bogawantalawa, Norwood, Dimbula, Talawakele, Dikoya, Agrapatanas, Madulsima.

August : Maskeliya, Bogawantalawa, Norwood, Dimbula, Talawakele, Dikoya, Agrapatanas, Rasagalla.

September : Maskeliya, Bogawantalawa, Norwood, Dimbula, Talawakele, Dikoya, Agrapatanas, Rasagalla, Kandy.

October : Maskeliya, Talawakele, Bogawantalawa.

November: Dimbula, Agrapatanas, Dikoya, Peradeniya, Bogawantalawa.

December: Bogawantalawa, Hatton, Kotagala.

1918.

January: Balangoda, Talawakele.

February: Talawakele, Pundaluoya, Nanu-oya, Kotagala.

March: Pundaluoya, Bogawantalawa, Maskeliya.

April: Maskeliya, Bogawantalawa.

May: Talawakele.

It is impossible accurately to determine the constant egg-laying seasons in one year: the census for several years must be taken before a true judgment may be made. January, February, July, and November appear to be constant, according to data of several years that is available :—

*In Bogawantalawa.*

July, 1906: 394,000 egg-masses were collected off two fields.

November, 1908: 18,000 egg-masses were collected off three fields.

June, 1907: 5,000 egg-masses were collected off two fields.

July, 1915: Many egg-masses were collected (number unfortunately not mentioned).

*In Pundaluoya.*

January and February, 1914: 187,137 egg-masses were collected off three fields.

January, 1915: 185,485 egg-masses were collected off three fields.

*In Talawakele.*

November, 1916, to February, 1917: 575,880 egg-masses were collected off two fields.

There are, as far as the investigator has been able to determine up to date, four broods of Tortrix per annum. The first brood makes its appearance in March. Between

July and October there are two broods in rapid succession, which overlap one another. The fourth brood appears in December.

As regards the percentage of eggs in a mass that hatch, there is considerable conflicting evidence. The results of laboratory and field experiments differ greatly; in the field 95 to 100 per cent. hatch, while in the laboratory the percentage is very much lower. It is difficult to account for this difference, for all laboratory experiments have been carried out in an environment approaching the natural element as closely as possible. Every detail to promote field conditions has been used: circulation of air, wind, rise and fall of temperature, rain, &c., yet nothing has reduced the difference that exists.

The following table shows the results of the average experiment in the laboratory on this subject :—

| Total Eggs in Mass. | Eggs hatched. | Eggs not hatched. | Total eggs in Mass. | Eggs hatched. | Eggs not hatched. |
|---|---|---|---|---|---|
| 155 | 129 | 26 | 150 | 137 | 13 |
| 84 | 63 | 21 | 199 | 154 | 45 |
| 163 | 141 | 22 | 168 | 158 | 10 |
| 135 | 23 | 112 | 209 | 197 | 12 |
| 109 | 71 | 38 | 84 | 75 | 9 |
| 52 | 30 | 22 | 157 | 144 | 13 |
| 157 | 130 | 27 | 135 | 115 | 20 |
| 85 | 72 | 13 | 95 | 55 | 40 |
| 61 | 61 | — | 188 | 155 | 33 |
| 94 | 64 | 30 | 93 | 56 | 37 |
| 75 | 68 | 7 | | | |
| 61 | 54 | 7 | 2,956 | 2,380 | 576 |
| 158 | 155 | 3 | | | |
| 89 | 73 | 16 | | | |

Egg-laying takes place in the evening and early morning.

*The Larva.*—The larvæ immediately upon hatching seek the underside of the leaf bearing the mass. They are more or less gregarious during the first week of life, living on the underside of matured leaves. If the egg-mass is a large one containing 125 to 150 eggs, many of the young larvæ crawl to other leaves. Little food is taken during the first week: they merely nibble small patches of the lower epidermis of the leaves.

The first instar (moult) is passed between the fifth and eighth day, and this would appear to be the most critical

period of the larval life, there being great mortality. Experiments show that some 30 per cent. die during the first moult.

Directly the first instar is over, the larvæ become solitary in their habits; they distribute themselves at night over the bush, generally ascending to the flush, where they spin two or more leaves together to form a shelter for themselves during the day. They are more or less quiescent in daytime, coming out of their shelters and feeding only at night.

The actual damage done to the tea is not so much due to the quantity they eat as to the quantity they destroy. They do not steadily devour a leaf, but nibble it here and there, bite into growing buds, gnaw round young shoots, twist and arrest the natural growth of the flush, and frequently completely nib off the stem bearing the flush. This latter point has been frequently observed in the laboratory, but it has been practically impossible to observe it in the field where the tea is regularly plucked; there has been no proof in the field that it is the larvæ as well as the pluckers that have broken off the flush.

After the first moult there is no variation in the larval life; as the larvæ grow and develop, they devour and destroy a greater quantity of leaves.

The number of times the larvæ cast their skins has not been definitely ascertained; but up to the present the points determined are: (1) Skin casting apparently takes place at night; (2) the cast skin, all but the head, is devoured by the larvæ; (3) the actual act of skin casting occupies but a short time. The period occupied in the larval stage is four to five weeks.

*The Pupa.*—The pupal period is passed under similar circumstances as the larva. When the time of pupation approaches, the larva ceases to feed, lying quiescent in its shelter of leaves. Gradually the larva shortens and becomes thicker, having a general "squat" appearance; just previous to the change into the pupa the head of the larva is depressed down between the first pair of jointed legs, the larval skin then splits along the dorsal surface from behind the head to the fourth segment. The head of the pupa now appears between

the split skin, and by wriggling on the part of the pupa the larval skin is gradually cast down to remain in a wrinkled state attached to the leaf and the cremaster of the pupa. The pupa is entirely enclosed in the shelter of folded leaves. The pupal period occupies five to eight days. In the male it is five to six days, and in the female seven to eight days. (See record of experiment, pp. 21 and 22.) The pupæ differ in size according to sex; in the male it is 7 mm., and in the female 11 mm.

*The Moths.*—The greater proportion of the moths emerge from the pupa in the early morning, and a small proportion in the late afternoon and evening. Those that issue from the pupæ in the morning are generally found in coition in the evening, and those emerging in the afternoon and evening are found coupled in the early morning. Never, to the investigators' knowledge, has fertilization been seen to take place between 9 A.M. and 3 P.M. It would, therefore, appear that some twelve hours elapse from emergence before fertilization takes place where male and female are in close proximity to one another; it is probable a greater time elapses before coition in the field; in the laboratory the average life of the male—having no contact with the female—is five days, which is an indication that four days can elapse before coupling takes place. The female is in union with the male once only, and the act of fertilization occupies three to six hours. The male dies some six hours after the completion of coition. The life of the female depends upon how soon after fertilization she lays her eggs. The average life is seven days, death taking place some twelve hours after the completion of egg-laying.

The adults do not by habit shelter in tea bushes. The instinct of the adult is to seek shelter affording protective resemblance, and not to expose themselves to danger in an environment of green. They are found resting on the tea leaves during severe attacks, or when driven from their natural retreats by wind, or prowling predaceous enemies, such as lizards. Their natural retreat is among dry leaves, or leaves resembling themselves in colour, branches of trees, dry brown refuse at the foot of the bushes, and very often on the ground itself.

TORTRIX LIFE-HISTORY EXPERIMENT.

To ascertain (*a*) duration of larval life; (*b*) duration of pupal period; (*c*) proportion of males to females; (*d*) prevailing colour of sexes.

| Larvæ hatched. | Number pupated. | Pupated. | Duration of larval life in days. | Emerged. | Duration of pupal life in days. | ♂ | Colour. | ♀ | Colour. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| All larvæ hatched on November 21, 1917. | 2 | Dec. 10 | 20 | Dec. 16 | 6 | 2 | Gray | — | — | 8 pupated after 3 weeks of larval life: 4 ♂, 4 ♀. |
| | 2 | Dec. 11 | 21 | Dec. 16 | 5 | 2 | do. | — | — | |
| | 2 | Dec. 11 | 21 | Dec. 18 | 7 | — | — | 2 | Ochraceous. | |
| | 2 | Dec. 11 | 21 | Dec. 19 | 8 | — | — | 2 | do. | |
| | 2 | Dec. 13 | 23 | Dec. 19 | 6 | 2 | Gray | — | — | |
| | 6 | Dec. 13 | 23 | Dec. 20 | 7 | 2 | do. | 4 | Ochraceous. | |
| | 1 | Dec. 14 | 24 | Dec. 19 | 5 | — | — | 1 | do. | |
| | 1 | Dec. 15 | 25 | Dec. 19 | 4 | — | — | 1 | do. | |
| | 2 | Dec. 15 | 25 | Dec. 20 | 5 | 2 | Gray | — | — | |
| | 2 | Dec. 15 | 25 | Dec. 23 | 8 | 1 | do. | 1 | Ochraceous. | |
| | 1 | Dec. 15 | 25 | Dec. 24 | 9 | 1 | Dark brown and gray | — | — | 63 pupated after 4 weeks of larval life: 33 ♂, 30 ♀, 8 dead. |
| | 8 | Dec. 16 | 26 | Dec. 22 | 6 | 8 | Gray | — | — | |
| | 4 | Dec. 16 | 26 | Dec. 24 | 8 | — | — | 4 | Ochraceous. | |
| | 3 | Dec. 16 | 26 | Dec. 25 | 9 | 1 | Gray | 2 | do. | |
| | 11 | Dec. 16 | 26 | Dec. 27 | 11 | 1 | do. | 2 | do. | |
| | 4 | Dec. 17 | 27 | Dec. 22 | 5 | 3 | do. | 1 | do. | |
| | 5 | Dec. 17 | 27 | Dec. 23 | 6 | 3 | do. | 2 | do. | |
| | 4 | Dec. 17 | 27 | Dec. 24 | 7 | 1 | do. | 3 | do. | |
| | 8 | Dec. 17 | 27 | Dec. 25 | 8 | 3 | do. | 5 | do. | |
| | 5 | Dec. 18 | 28 | Dec. 23 | 5 | 5 | Orange-brown and gray | — | — | |
| | 2 | Dec. 18 | 28 | Dec. 25 | 7 | — | — | 2 | Ochraceous. | |
| | 2 | Dec. 18 | 28 | Dec. 27 | 9 | — | — | 2 | do. | |
| | 2 | Dec. 19 | 29 | Dec. 24 | 5 | 2 | Gray | — | — | 63 pupated after 5 weeks of larval life: 30 ♂, 33 ♀, 5 dead. |
| | 1 | Dec. 19 | 29 | Dec. 25 | 6 | — | — | 1 | Dark brown | |
| | 4 | Dec. 20 | 30 | Dec. 24 | 4 | 2 | Gray | 2 | Ochraceous. | |
| | 11 | Dec. 20 | 30 | Dec. 25 | 5 | 8 | do. | 3 | do. | |

| Larvæ hatched. | Number pupated. | Pupated | Duration of larval life in days. | Emerged. | Duration of pupal life in days. | ♂ | Colour. | ♀ | Colour. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| All larvæ hatched on November 21, 1917. | 7 | Dec. 20 | 30 | Dec. 26 | 6 | 3 | Gray and brown | 4 | Ochraceous. | 63 pupated after 5 weeks of larval life: 30 ♂, 33 ♀, 5 dead. |
| | 6 | Dec. 20 | 30 | Dec. 27 | 7 | 3 | Gray | 3 | do. | |
| | 5 | Dec. 20 | 30 | Dec. 28 | 8 | — | — | 5 | do. | |
| | 4 | Dec. 21 | 31 | Dec. 26 | 5 | — | — | 4 | do. | |
| | 7 | Dec. 21 | 31 | Dec. 27 | 6 | 2 | Gray | — | — | |
| | 2 | Dec. 21 | 31 | Dec. 28 | 7 | — | — | 2 | Gray | |
| | 5 | Dec. 23 | 33 | Dec. 28 | 5 | 5 | Gray | — | — | |
| | 3 | Dec. 23 | 33 | Dec. 30 | 7 | — | — | 3 | Ochraceous. | |
| | 1 | Dec. 23 | 33 | Jan. 3, 1918 | 10 | — | — | 1 | do. | |
| | 1 | Dec. 24 | 34 | Dec. 29 | 5 | 1 | Gray | — | — | |
| | 1 | Dec. 24 | 34 | Jan. 3, 1918 | 9 | — | — | 1 | Ochraceous. | |
| | 3 | Dec. 26 | 36 | Dec. 31 | 5 | 3 | Gray | — | — | |
| | 2 | Dec. 26 | 36 | Jan. 1, 1918 | 6 | 1 | do. | 1 | Ochraceous. | |
| | 3 | Dec. 26 | 36 | Jan. 3, 1918 | 8 | — | — | 3 | do. | |
| | 6 | Dec. 27 | 37 | Jan. 3, 1918 | 7 | 2 | Gray | 4 | do. | 8 pupated after 6 weeks of larval life: 2 ♂, 6 ♀. |
| | 2 | Dec. 27 | 37 | Jan. 4, 1918 | 8 | — | — | 2 | do. | |
| | 155 | | | | | 69 | | 73 | | (+ 13) |

*Resumé.*

In the ♂♂

1 instance of 4 days.
9 do. 5 do.
8 do. 6 do.
3 do. 7 do.
2 do. 8 do.
2 do. 9 do.
1 do. 11 do.

∴ Pupal period for ♂♂ 5–6 days.

In the ♀♀

2 instances of 2 days.
4 do. 5 do.
5 do. 6 do.
7 do. 7 do.
7 do. 8 do.
2 do. 9 do.
2 do. 10 do.
1 do. 11 do.

∴ Pupal period for ♀♀ 7–8 days.

## Protective Resemblance.

Experiments were made to ascertain whether the variation of colour in the adults was dependent upon the environment of the larvæ and pupæ. Larvæ just about to pupate were isolated and subjected to surroundings of various colours, and allowed to pupate and remain until the imagines emerged on surroundings of white, red, brown, and green. Those in the white environment were normal in colour and markings. Those submitted to red were normal, except in one instance, a male whose markings were nearly black. Those subjected to brown were in no way irregular. The green environment gave one instance of a female with black shoulders.

The white constituted a radical difference from the natural surroundings ; the red, the complement of green—the natural element of larval surroundings ; while brown constituted an environment the larvæ possibly meet frequently, and which the adults endeavour to immitate or resemble in their colour scheme, namely, that of dry leaves, roots, branches, and even the soil itself.

The results of the experiments showed that the variation in colour of the adults was not accentuated by the environment of the larvæ before pupation or that of the pupæ. The question of food does not appear to influence the colour of the adults, for from the twenty-one odd plants they have been taken from and fed on, no marked variation of the adults was perceptible.

## Mortality among Larvæ, and Rate of Increase of the Pest.

The mortality among the larvæ is very high. Thirty per cent. of a brood die at the first moult, and a further 40 per cent. die through natural causes : exposure to inclement weather, overcrowding, scour, parasites, and predaceous enemies. Only 30 per cent. of a brood reach maturity ; in other words, only 45 larvæ of every 150 reach the reproductive or adult stage ; and, as the proportion of males to females is practically equal (there being a very slight difference, according to data of the last year,* in favour of the females), only 22

* This is contrary to the usual scheme governing sexual instinct in insects. Fertilization is the object for which nature produces individuals, and she must necessarily be anxious for its most easy and securest attainment. One of the most usual means consists in the males being more numerous than the females.

individuals of every 150 are egg-layers. The rate of increase of the insect is therefore as follows :—

A single egg-mass of 150 eggs produces 45 adults, of which 22 are females.

First Brood : A single female produces 22 females.

Second Brood : 22 females produce 3,380 eggs, of which 30 per cent. reach maturity, the half being females = 507.

Third Brood : 507 females produce 76,050 eggs, of which 30 per cent. reach maturity, the half being females = 11,407.

Fourth Brood : 11,407 females produce 1,711,050 eggs, of which 30 per cent. reach maturity, namely, 513,315, half of which are females = 256,657.

Therefore, from a single female in one year, allowing only 30 per cent. of every brood to reach maturity, 513,315 individuals will arise.

### Larval Environment as Influence to Sex.

Two experiments with controls were opened to ascertain what influence the larval environment might have on the sex of the adults. The larvæ for these experiments were taken from the field in a semi-matured state. Lot 1 was treated normally : natural field conditions. Lot 2 was subjected to light feeding, which was gradually reduced until the colony were in a state of semi-starvation. The results of lot 1 and the controls were normal and in agreement with all other life-history experiments, namely, an equal proportion of males and females. Many individuals of lot 2 died before reaching pupation ; and those that emerged were males. From the number of deaths in lot 2 and the proportion that emerged in comparison with the controls showed that sex was not determined by environment, and that the males were not actually in excess of the females, but that the males were more capable of enduring adverse circumstances, while the females were eliminated.

### Preventive and Remedial Measures.

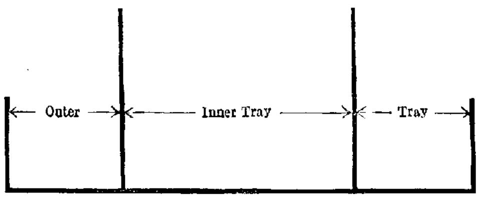
*Egg-collecting.*—The fact that the egg-masses are conspicuous objects and readily seen would lead to the belief that the wholesale collection of egg-masses by gangs of coolies would be an effective way of destroying the insect. It has proved

successful in some instances, but in the majority of cases though the collecting has been done assiduously and systematically, the benefit has been practically negligible, while the expenditure has been great.

The collection of egg-masses as an economical measure can only be advocated in fields that are four or five months from pruning, because the foliage is not so dense as on bushes further from pruning, and the examination of every leaf on such a bush is an easy and quick matter ; whereas on a bush in full leaf a thorough examination is practically impossible, and many egg-masses escape notice.

The egg-laying seasons previously mentioned for various districts for 1917–18 will be a guide for the next year ; and those fields a few months from pruning should be examined and the egg-masses collected and burnt, or sent into the laboratory for examination for parasites.

There is a general opinion that egg-masses should not be destroyed in case the existing egg-parasites are destroyed as well. This matter is simply overcome by using the tray suggested here. The tray may be made from old kerosine tins, or of wood, and consists of " a box within a box."




The inner box or tray is to hold the leaves containing the egg-masses, and may be of any dimension according to the quantity of egg-masses collected, while water is placed between it and the outer tray. The distance between the inner and outer tray should be in accordance with the height of the inner tray, so as to ensure that larvæ that hatch may not escape by suspending themselves from the top edge of the inner tray by means of their silken threads and being blown over the water between the two boxes. If the inner box be 3 feet high, the space for water between the boxes should be at least 1 foot to 18 inches.

By filling the inner tray with leaves bearing egg-masses and leaving them for a week or ten days, any egg-parasites there may be will hatch and escape, while the larvæ from unparasitized eggs will not escape, and after ten days they can be destroyed in the burning of the leaves.

*Collecting Larvæ.*—The collecting of larvæ is really not an economical measure, for the partial relief to the bush is not appreciable, and time and money is wasted. Planters should, however, get their pluckers to crush the groups of curled leaves while plucking, and thus destroy the larvæ they contain. By this means little time is wasted, a special gang of coolies is not required, and a great number of larvæ may be killed systematically.

In the case of a severe attack, where every bit of flush on every bush contains larvæ, table pruning or top pruning has been found to be of benefit. The top of the bush is pruned flat, and all prunings gathered and burnt or buried. If buried, care must be taken that the prunings are buried the same day, in order that the larvæ do not escape from the leaves in the evening.

Many planters believe in the *laissez faire* principle, to leave an attack and it will " work itself out," while the loss they incur by this means will be readily compensated for by a renewed and more vigorous flushing after the attack.

It would appear that bushes give a more vigorous flush after an attack, but that an attack will " work itself out " is not altogether true. It depends entirely upon the locality, the strength of the bushes, and the prevalence of " wilt "—the polyhedral disease. If bushes are vigorous and well manured and can maintain a good production of leaf, the attack will carry on indefinitely, unless " wilt " appears in the colonies. For the more food there is for the insect, the more vigorous and healthy it becomes.

Where bushes are of poor quality, due to the jât (?) or the soil or the lack of manure, an attack will work itself out in time, for the bush cannot supply the necessary amount of leaf for the larvæ, and they, through lack of food, lose vitality and become diseased. But, though the attack is " worked out," the damage done to the bushes must be very severe, and though there is a temporary compensation in flush afterwards, the wood or frame of the bush will suffer material depreciation.

It would be a source of anxiety to the planter who is endeavouring to keep Tortrix down by the systematic collection of egg-masses on fields lately pruned, and the crushing of the larvæ by gangs of pluckers, to know his neighbour is carrying on the *laissez faire* principle. For undoubtedly his fields are the source of contamination of his valley, as the females will seek fresh and luxuriant fields in which to lay her eggs.

*Tortrix "Breaks."*—A system of wind belts or "Tortrix Breaks" may prove of benefit in checking the wholesale distribution of the pest. The investigator would suggest that planters allow two adjacent rows of tea bushes, along those ridges swept by the south-west monsoon, to grow up into seed bearers, as they would make a most effective break to the flight of Tortrix, prevent the distribution of the pest through the fields, and when the insect is seen to be established in these breaks, remedial measures in the form of insecticidal sprays could be easily and economically used on them. No injury would result to the seed bearers; competitive markets could not accuse us of using poisons on marketable tea; the "breaks" would act as traps to the pest, and the pest would be killed by the application of insecticides, independent of parasites and natural enemies.

By sacrificing two rows of bushes for a few years by allowing them to come into seed bearers will do the bush as a future profitable concern no harm that I am aware of, and this opinion has been arrived at after consultation with planters on the subject. Should these "breaks" prove valuable, and the bushes have remained as seed bearer-breaks long enough, they can be pruned down, and the next two adjacent rows used as "breaks" for a few years.

*Dadaps* make fairly good flight breaks, being at the same time excellent for manurial purposes, but they do not make such good breaks as tall tea bushes, simply because the adult Tortrix can fly between the head of the Dadaps and the top of the tea into the field. Tea bushes grown to seed bearers make a more impenetrable barrier.

*Grevilleas*, as has been stated, harbour Tortrix; the mere fact of harbouring Tortrix show they are breaks to the insect flight, but unfortunately they are too high to make spraying either an easy or economical measure.

*Acacias* form good flight breaks and excellent breeding grounds for the pest. They, too, do not offer economical remedial measures.

One estate that suffered badly with Tortrix in 1909 and again in 1913 in fields devoid of trees other than Dadaps was planted thickly with Acacias, and the tea on these fields has not yet been attacked by Tortrix since the Acacias grew up to a good height. Acacias do not stop Tortrix attacking tea; the Tortrix is there in the Acacias, and when circumstances are such that the colonies in the Acacias become too numerous and lack food, the insects will drop into the tea. Could these "breaks" be sprayed economically when the colonies show signs of overcrowding the insect would be killed and the threatened danger to the tea removed.

The point to be realized is, the numerous shade and manurial trees do not keep Tortrix away. They act as breaks to the flight and distribution of the moths; the moths lay their eggs in these trees, and the pest propagates and remains in them until the colonies become overcrowded, when the insects drop to, and attack, the tea.

When a system of flight breaks that could be easily sprayed can be arranged, a big step will have been taken towards the control of the pest. The system of seed bearers is suggested as meeting the requirements of the case.

Because Tortrix is not to be seen in the tea, it is not to be thought that it is not threatening the crop. It is there, an ever-present menace to the tea.

*Cultivation.*—There is little doubt that good cultivation promotes strong healthy plants, and it is obvious that the healthy bush can more vigorously repair the damage done by Tortrix than the ill-nourished bush. The benefits to be derived from good cultivation are manifold, and, from the Tortrix point of view, every endeavour should be made to produce strong healthy plants.

*Trapping the Adults.*—It is a well-known fact that branches of dry Grevillea leaves attract the moths; and the suggestion made by Mr. E. E. Green of placing such branches suspended from sticks among the tea appears to be a good method of trapping the adults.

The moths come to, and settle upon, the dry leaves; a cooly with a sack, the mouth of which is kept open by means of a circular band made from a branch of a tree, envelopes the Grevillea branch in the sack and beats it upon the ground, thus killing many moths. Mr. Green states a cooly should do about 10 acres a day where the traps are some 40 feet apart. This trapping should be employed on the first appearance of the moth.

PARASITES.

Parasites are the natural enemies of insects, and act, when every encouragement is given them to propagate, as a check to the increase of pests. They are agents that assist in maintaining the balance of nature in the insect world. There is no lack of parasites attacking Tortrix, but unfortunately it is only in one or two areas that they are established to such a degree as to be of benefit in reducing and keeping down the pest.

There are two parasites attacking the eggs of Tortrix, but the percentage is so very low that it cannot be said they are of any benefit at the present moment. They were recorded in May and June, 1917, from Hangurankette, Alton, Midlothian, and Mottingham estates, and although over 15,000 egg-masses have been carefully examined during the year, it has only been within the last week of May, 1918, that two masses from Hangurankette showed the parasite, and only three eggs in each mass were parasitized.

Egg parasites are one of the most important factors in reducing a pest. If they are cultivated and thrown into the field at rates superior to the rate of increase of the pest, they are bound to prove of benefit. The first point of consideration is, will the expenditure necessary for the propagation and distribution of the egg-parasites prove ultimately of economic value? The only way this can be ascertained is to work out the rate of increase of the parasites as against that of the host, together with the climatic influence on the development of both; and this can only be done if estates will send in sufficient egg-masses for investigation purposes.

There is no doubt that the egg-parasites are the most valuable when established in sufficient numbers, for they

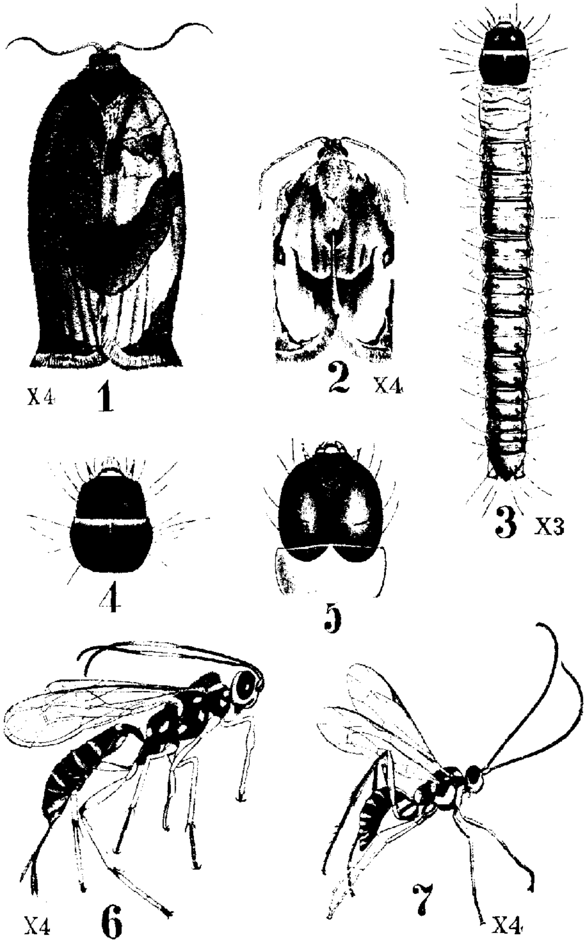
check the pest at the commencement of its life, namely, in the egg. Larval parasites are certainly of benefit, but they do not kill their host until the host has completed the damage it is responsible for; they reduce the number of the second generation, but egg-parasites reduce the number of the first generation and kill the pest before it does any damage at all.

The investigator is assured from practical experience in parasitology that should egg-parasites appear in sufficient abundance to permit of extensive propagation, there is little doubt that by the application of time and money for the development and distribution of these parasites the pest would be systematically reduced along natural lines to such an extent that the adoption of artificial measures to local outbreaks would immediately check the pest.

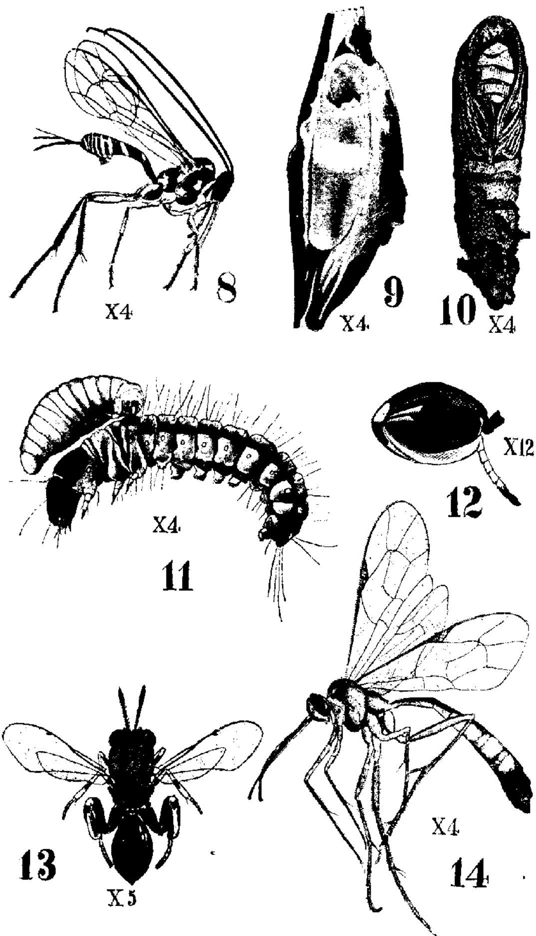
Parasites will never kill out the host, for the death of the host means the death of the parasite itself; but they will reduce the pest, when propagated and encouraged, to such a balance that no material damage or loss of crop is incurred. Should the pest at any time get the upper hand of the parasite, artificial remedial measures on a small and inexpensive scale would be able to reduce the pest down to the level of the parasite control.

This point warrants emphasis. If the egg-parasites can be steadily and systematically propagated, there should be little difficulty in establishing them, with the knowledge of the egg-laying seasons of the various districts and their climates, and, assisted by the larval parasites that exist, the question of reducing the pest should not be a difficult one.

Insects have been known to change their habits according to circumstances. When the host of a beneficial insect has been killed out, the beneficial insect has accommodated itself to circumstances and become a pest. The investigator sees little fear of such a thing happening with egg-parasites, for should there not be sufficient Tortrix for the Tortrix egg-parasites to exist upon, they may possibly accommodate themselves to circumstances and attack the eggs of another species of insect; but this change would be more of a benefit than otherwise, and it is extremely doubtful that they would become hyperparasites.




1. FEMALE; 2. MALE; 3. FULL-GROWN LARVA, SEEN FROM ABOVE; 4. HEAD OF FULL-GROWN LARVA; 5. HEAD OF LARVA JUST EMERGED FROM EGG; 6. LISSONATA SPP., PARASITE OF LARVA; 7. MALE PHYTODIÆTUS CAPUÆ, PARASITE OF LARVA.




8. FEMALE PHYTODIETUS CAPUÆ; 9. COCOON OF P. CAPUÆ IN FLUSH; 10. TORTRIX PUPA, SHOWING EXIT OF LEUCOSPIS PARASITE; 11. MATURED LARVA OF P. CAPUÆ FIXED TO TORTRIX LARVA; 12. HIND LEG OF LEUCOSPIS, SHOWING CLOSE CONTACT OF FIRST AND SECOND JOINTS; 13. LEUCOSPIS SPP., PARASITE OF TORTRIX PUPÆ; 14. PLEURONEUROPHION ERYTHROCERUS, SUSPECTED PARASITE OF LARVA

The parasites attacking Tortrix known up to the present possibly number eight:—Two on the egg; four (and one suspect) on the larva; one on the pupa.

Of the egg-parasites recorded, there are two species belonging to the family Chalcididæ, genus Trichogramma. They are minute, yellowish insects measuring $\frac{1}{4}$ to $\frac{1}{2}$ mm. in length. One parasite, *Trichogramma minutum* (?), lays two to three eggs in each of the Tortrix, while the other, *Trichogrammatoeida nana* (?), lays but one.

At present only 3 per cent. of an egg-mass appears to be parasitized, and only one egg-mass in a thousand shows this percentage.

*Phytodiætus capuæ* (Fig. 8).—The adult is a black brightly-yellow marked insect, "wasp-like" in appearance. The eyes are black and the face yellow. Antennæ are slender and slightly longer than the body. The abdomen is a little longer than the head and thorax together, narrow; the segments possess greenish-yellow margins; the basal segment is somewhat flattened. The legs are pale yellow and long; first and second joints are straw colour; the third and fourth joints of the hind legs blackish, also all the "feet" or last joints. The wings are clear and iridescent, with a stigma, or clouded portion at the upper margin, darkish yellow. Length 6 to 8 mm. This "wasp-like" insect is an ectoparasite of the Tortrix caterpillar; its larva is the little maggot-like structure found fastened to the back of the Tortrix just behind the head.

The female parasite flies by day, searching the curled leaves of the tea bushes to ascertain if they contain Tortrix larvæ. She may often be seen running hither and thither on a curled leaf, tapping it here and there with her antennæ, and when she has satisfied herself there is a caterpillar within the curled leaf, and its position, she presses her ovipositor or "sting" through the leaf into the "neck" of the Tortrix and lays an egg on the larval skin, to which it is fixed by means of a minute peduncle. It is not always she strikes the exact position behind the head so necessary for the existence of her young, for larvæ have frequently been taken bearing the marks where parasites have been fixed on the sides and low down on the body. It is evident a single larva may be parasitized several times, for

they have been found carrying two or three "maggots" of different ages.

In the course of a few days (the incubative period has not been definitely ascertained) the egg splits and the head of the larva emerges and fixes itself to the skin of its host. Thus, the parasite is attached by both extremities to the Tortrix, and generally it occupies a transverse position, *i.e.*, it lies across and not along the host. This position is necessary for its existence, for as its development progresses, were it to occupy a position along the back, the Tortrix could sufficiently injure it to cause its death. The presence of the parasite in no way interrupts or hinders the ecdyses of the host.

When maturity is reached (in about four weeks) the Tortrix dies, and the parasite releases its buccal hold on its host (Fig. 11), then throws a cocoon of semi-transparent yellow-white over itself, which hardens, and is fixed to the leaf by means of white silken strands (Fig. 9). (The investigator has unfortunately not caught the moment of transition from "maggot" to cocoon.) From one to two days after the formation of the cocoon the maggot turns into a pupa, and in twelve days' time from the formation of the cocoon emerges as an adult.

*The Male* (Fig. 7).—Practically the only difference between the male and female, without going into minute anatominical differences, is that the male is smaller, measuring 4 to 6 mm. The colours are not so bright, and the first and second joints of the hind legs are browner than yellow. The basal joints of the antennæ are somewhat pale yellow on their underside; this difference can only be detected with a strong lens.

The cocoon of this particular male was a dark brown, and not the translucent yellow-white of the female. The pupal period occupied eleven days.

This larval parasite is one of the most thoroughly established Tortrix parasites in the Island, and is present in fairly high percentage on eighteen estates. It should be encouraged in every way.

Those larvæ seen to be attacked should be left on the bushes. Where the parasite is established, birds should not be encouraged. There is a great deal of difference of opinion on the question of the good birds do in the way of devouring

Tortrix, and many have rightly suggested that the adult *Phytodiætus capuæ* possesses "warning colouration," which makes it exempt from the attack of insectivorous birds; and, therefore, to have this parasite and birds both waging war against Tortrix will materially reduce its numbers. Seldom is *Phytodiætus capuæ* found where birds are established, because the birds do not discriminate between Tortrix larvæ which are parasitized and those which are not, so that the birds by devouring the few larvæ they do, devour also the parasites fixed to the larvæ. The parasite is the natural—not the promiscuous—enemy of the Tortrix, and its rate of increase is greater than that of birds. It is therefore of much greater value and importance as a check to Tortrix than any insectivorous bird can be.

The fact that Tortrix is distributed over tea areas by the south-west monsoon is an inducement to assist and encourage the propagation of the parasite in order that it may also be distributed with the Tortrix. Birds do not follow Tortrix, but remain in those localities where every encouragement is given them. The best principle would be to give every encouragement to the natural enemy of our pest and check the agents that reduce this natural enemy.

Fig. 6 shows another Tortrix larval parasite which is somewhat similar to *Phytodiætus capuæ* in its mode of life. This insect is not far removed from the genus *Phytodiætus*, belonging to the genus *Lissonota* Gravenhorst. It possesses "warning colours" in a more subdued form to *P. capuæ*, but may be easily mistaken for it; it is, however, larger, measuring 10 to 12 mm.; dull black with markings of orange-brown; the legs are similar in colour to *P. capuæ*, but lack the black third and fourth joints of the hind legs; the "feet" are black. The most distinguishing points are the antennæ, which are black, with the middle third portion yellow or white. This parasite appears to be comparatively rare in our tea fields at present.

*Pleuroneurophion erythrocerus*, Cameron (Fig. 14).—It cannot yet be definitely stated that this insect is a larval parasite of Tortrix. It is a suspect, and has frequently been captured while hovering around curled leaves containing Tortrix larvæ, but never have the innumerable parasitized larvæ taken in the fields and bred in the laboratory given

*P. erythrocerus.* A short description of the insect will enable planters to recognize it, and so be able to watch and report on its behaviour. It is 14 to 15 mm. in length, and of a darkish yellow. The head and thorax yellow. Abdomen a darker yellow than the head and thorax, darkening to brown at the apex, and laterally flattened. Legs dark yellow with the two front pairs of a lighter shade. This insect is fairly common, and if proved to be a parasite of Tortrix larvæ should be encouraged.

*Proctotrypidæ.*—This family of parasites are in the great majority of cases parasites of insect eggs, but in one single instance the investigator has had sent in from Madulsima an extraordinary case of Proctotrypid parasitization of a Tortrix larvæ, which warrants recording. Glancing at the larva casually it appeared to possess four distinct leg-like processes projecting from the lower surface of the fourth to the seventh segments, a single process to each segment. On a closer examination they proved to be the pupæ of a parasite, which, upon emerging, was identified to be of the genus *Proctotrypes*.

Dr. Sharp has recorded one instance of such parasitism,* where the pupæ of the parasite projected from the body of the host, which was a beetle larva; a pair of the parasites depended from the lower surface of each segment of the host. I am of belief it is of extremely rare occurrence.

Another larval parasite of Tortrix very similar in its habit of pupation to *Phytodiætus capuæ* has on several occasions been sent in from Talawakele district. The adult measures 5 to 6 mm., is black, with an orange-red thorax. Head black; antennæ black; mesonotum, or anterior portion of thorax, orange-red. Abdomen black, with a yellow transparent portion on either side extending from the junction of the thorax to the apex of the abdomen. Hind legs black, medium and anterior pair yellow. This insect forms a cocoon very similar to that of *P. capuæ,* only that, instead of being yellowish-white and translucent, it is white and wooly-like in appearance, and smaller. When the wool-like substance is removed it is translucent. As yet the insect has not been classified.

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* Peripatus. Myriapods and Insects, Pt. I., Camb. Nat. Hist., p. 535.

The pupal parasite, *Leucospis* sp. (Fig. 13), though belonging to the same family of insects as the egg-parasites mentioned, is an entirely different insect. It measures 5 to 7 mm., and is black and yellow in colour. It cannot readily be mistaken, as it is a substantial, stout, bee-like insect. The head is dull black and pitted; eyes shiny black, antennæ elbowed. Thorax large, dull black, and pitted. Abdomen shiny black; the two front pair of legs yellow with black markings; the posterior coxæ (first joint of the hind legs) are enlarged, black, with a yellow spot at the insertion of the second joint; the second joint is yellow, and lies in close contact with the first (Fig. 12). The wings are clear, transparent, and without cells, possessing but a single nervure. This insect lays its eggs (apparently a single egg, for never has more than one *Leucospis* emerged from a single pupa) within the pupa of the Tortrix. The "maggot" on hatching devours the contents of the pupa, pupates within it, and emerges from the upper part of the ventral surface of the Tortrix pupa (Fig. 10).

Owing to the difficulty of obtaining sufficient material, the life-history of this parasite has not as yet been worked out. Like the other parasites, with the exception of *P. capuæ*, they appear to be fairly scarce.

"*Wilt*," *the Polyhedral Disease.*—From data of the subject of Tortrix accumulated during the last fifteen years, it is very evident that Tortrix comes in three-year cycles. After investigation, the reason for these cycles has been ascertained. It is entirely due to the "wilt" disease.

Wilt is an ultra-microscopic disease of insects, originating within the nuclei of the hypodermal, fat, tracheal matrix, and blood cells of caterpillars. What the disease actually is appears not yet to have been ascertained by the scientists working upon it. It gives negative results bacteriologically, and, according to Glaser and Chapman,* the following possibilities are suggested: "(1) That the polyhedral bodies (about the only indication one has of the disease) are themselves parasites; or (2) the etiological factor of the wilt disease is a minute filterable organism independent of the polyhedra; or (3) if the virus is filterable, it may be genetically related to polyhedra."

* Glazer. Jour. Agri. Research, Vol. IV., No. 2, p. 101.

What the disease is, its pathology and etiology, can be dismissed for the moment. It is well established in the colonies of the Tortrix larvæ, and is responsible for a high percentage of their deaths ; but instead of keeping the pest in check permanently, it appears to come in " waves " or cycles of three years. The reason of this is easily understood after reading the literature of the subject.

It appears that immunity to the disease is possible.† Individuals of a colony can be absolutely unaffected by the disease, while 90 per cent. of their species are dead and dying. In a heavily infested area an epidemic of the disease occurs. Lack of food causes larvæ to lose their vitality, and this produces greater susceptibility to the disease. Having susceptibles and immunes in every colony, it is possible to account for the three-year Tortrix cycles. At the present time there is little of the pest, practically only immune individuals existing, and wilt not having individuals to work upon becomes latent. The immunes propagate. In the second year Tortrix is more or less abundant, and few susceptibles appear in the colonies, but this generation is strong, and does not become overcrowded or lack food, therefore wilt, though here and there among the susceptibles, makes little progress. In the third year Tortrix is in abundance. A bad attack is the result. The susceptibles are numerous. With overcrowding and lack of sufficient food the colony loses vitality, and, let us say, 90 per cent. of the colony are susceptible to the disease. Having abundance of individuals to work upon, wilt flourishes and ultimately kills out all but those possessing immunity. Now we start the second cycle from the immunes, working up gradually to a state of low vitality and overcrowdedness in the sixth year —the state necessary for the increase of the polyhedral disease. Thus we get Tortrix in waves or cycles.

A careful study of this disease as affecting Tortrix, and the possibility of utilizing it as a permanent check to Tortrix, is being undertaken.

*Insecticides.*—It is believed that were arsenical compounds to be employed in killing the insect on the tea, the fact might

† Glazer and Chapman. Jour. Econ. Ento., Vol. VI., No. 6, p. 487.

be used by rival markets to depreciate the market for Ceylon teas, but as the spraying of large areas of tea for Tortrix is anything but an economical measure, the only possible use of arsenates that might be suggested is in the spraying of Flight Breaks, from which no tea would be made.

Experiments are also being instituted to find, if possible, a good, cheap, non-poisonous spray which may be used on tea in small, serious, local outbreaks of the pest.

*Birds.*—A paper upon "Economic Ornithology in Relation to Tea Tortrix" appeared in the December, 1917, number of the "Tropical Agriculturist." This article brought to the notice of planters the fact that the encouragement of insectivorous birds on estates for the purpose of checking Tortrix had little material effect. There was evidence that birds effect little in the check of Tortrix, and might be responsible in some instances for its increase. That evidence has received further confirmation. Numerous birds have been sent in from areas containing Tortrix, and the contents of their crops examined. So far every case shows that 90 per cent. of the undigested material was the remains of minute Coleoptera. Never has evidence of the moth been found in the crops. If larvæ have been devoured, there is a likelihood that the larval parasites of the Tortrix have been devoured also.

*Bats.*—At the meeting of the Agricultural Experiment Committee of November, 1917, when the relationship of birds to Tortrix was under consideration, it was suggested that investigations be made into the economic importance of bats as affecting Tortrix.

Numerous bats have been dissected and their stomach contents examined. Unfortunately the majority of the bats sent in for examination have come from one district, and have been of the same genus, with one exception. The bats were the Pipistrel tribe (Vespertilionidæ), *Harpyiocephalus cyclotis,* and showed beetle antennæ, mandibles, legs, and chitinous abdominal plates. Only in one instance was there evidence of lepidoptera, a butterfly wing being present in the stomach.

*Homona coffearia* Nietner.

*Male.*—Gray. Head and thorax gray, densely scaled; eyes rufous; antennæ ciliated, filiform, reaching to medial

portion of wing; palpi short, curled, ascending, with appressed scales, terminal joint short; thorax with crest of scales on dorsal surface. Fore wing gray, narrow, with an oblique slightly sinuous medial band of light brown from costal margin to centre of dorsum; a dark gray punctum bordered with black at centre of costa; a sinuous brown band crossing apex from costa to termen; termen arcuate, fringed with gray scales; costal fold, curled towards the upper surface, densely scaled; 3 from angle, 7 and 8 stalked, 7 to termen. Hind wing unicolorous, dark gray, fringed, without basal pecten, 3 and 4 connate, 5 approximate to 4 at base, 6 and 7 stalked. Posterior tibia with a pair of medial spurs as well as an apical pair. 15 to 17 mm. expanded.

*Female.*—Ochraceous. Head and thorax ochraceous, eyes black, sometimes rufous; antennæ simple, filiform, as long as head and thorax; palpi as in male; thorax without crest. Fore wing ochraceous with a darker ochraceous patch on the shoulder, and oblique slightly sinuous medial band of the same shade from costal margin to dorsum, a similar band across apex, borders of the atomi rufous; apex pointed, termen arcuate and fringed; no costal fold; venation as in male. Hind wing unicolorous, cupreus, fringed; venation as in male. The wings when at rest lie over the body, their outline being of the same shape as the section of a bell. Posterior tibia with medial as well as an apical pair of spurs. 25 to 28 mm. expanded.

*Pupa.*—Naked. Thorax fulvous, darker on the dorsum; wing-cases well defined and dark fulvous; ventral median area bronzus in male; eyes rufescent; abdomen tawny, dorsum adminiculate, adminiculæ transversely placed, rescuspate, two rows to each segment with the exception of the penultimate and ultimate segments, anterior rows more developed than posterior; two dorso-lateral rows of cilia; extending to the penultimate segment, each segment bearing four cilia; penultimate segment thinly cirrose, recuspate; cremaster stout, flattened dorsally, eight-spined, four apically bifarious, a pair dorso-laterally, a pair ventro-laterally placed. Male 7 mm. Female 11 mm.

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